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Comments to the NSET Subcommittee and the NNI participating agencies on "*Prioritization of Environmental, Health, And Safety Research Needs for Engineered Nanoscale Materials*"

Prioritizing the environmental, health, and safety (EHS) research needs and funding priorities for engineered nanomaterials is a significant challenge because of the uncertainties associated with current scientific understanding of nanomaterials' properties and life-cycle impact. The results of the research priority rankings, as they are presented in the document, are reasonable. While the rankings are no doubt the product of extensive discussion, the process by which each task force arrived at its final rankings is opaque. We recommend that the Nanotechnology Environmental and Health Implications (NEHI) Working Group consider formal multi-criteria decision analysis (MCDA) tools as a methodologically sound approach for the prioritization of research needs as well as for the subsequent prioritization of research gaps and specific proposals for funding. The use of formal MCDA tools would maximize the utility of agency investment in nano-EHS research.

Generally, MCDA methods utilize a decision matrix of criteria and performance scores to provide a systematic analytical approach for integrating risk levels, uncertainty, and valuation, which enables evaluation and ranking of many alternatives. Specifically, MCDA tools are useful in identifying data research gaps in a transparent and justifiable manner as well as for the prioritization of information needs given stakeholder preference and agency mission (Linkov et al., 2007a). Multiple publications are available on the use of MCDA tools (*e.g.*, Figueira *et al*., 2005), and they have been applied to environmental technology prioritization, sediment management, and resource allocation, among other tasks (Linkov *et al,* 2007b, Linkov *et al*., 2006a, 2006b).

In our recent paper (Linkov et al., 2007a) we used MCDA to develop a prioritization methodology for oil spill response performance metrics. This NOAA-funded project resulted in a comprehensive and structured process for selecting the metrics for any given situation, and vetting these metrics with stakeholder groups in a way that incorporates their value judgments as well as scientific modeling and risk analysis. The framework allows visualization and quantification of tradeoffs and is consistent with the Government Performance and Results Act (GPRA).

In addition, we have previously used decision analysis to carry out a capability gap prioritization for the Joint Service Small Arms Program (JSSAP), and our results were used to inform military funding decisions. The program had decided upon several tasks that it wished to be capable of performing to various degrees of proficiency in three time periods, and it had identified metrics to be used in measuring current performance. We used decision analysis to assign weights to each time frame, task, and measure, and we used this to produce a prioritization of the corresponding gaps.

Finally, we are currently working on the risk-informed decision making (RIDM) framework for the Louisiana Coastal Protection and Restoration (LACPR) project and the Mississippi Coastal Improvement Program (MsCIP) (Bridges et al., 2007). RIDM draws from current practice in the fields of risk and uncertainty analysis and multi-criteria decision analysis to provide an approach for defining attributes that capture a diverse set of objectives and establishing a set of preference weights that reflect the priorities of different stakeholder groups. It also provides a method for deriving quantitative scores for the numerous alternative coastal infrastructure plans that are now under consideration by the US Army Corps of Engineers.

In summary, the current NEHI Working Group approach to nanotechnology research prioritization and upcoming gap analysis could be strengthened if it were supplemented with a transparent decision-making framework. Multi-criteria decision analysis could provide such a framework.

References:

- Bridges, TS, Suedel, BC, Kim, J, Kiker, G, Schultz, M, Banks, C, Payne, BS, Harper, B, and Linkov, I. (2007, in preparation). Risk-Informed Decision Making Applied to Coastal Systems: Sustainable Management of Flood Risks and the Environment. *Risk Analysis.*

- Figueira J, Greco S, Ehrgott M, eds. (2005). *Multiple criteria decision analysis: State of the art surveys*. New York (NY): Springer.

- Linkov I, Satterstrom FK, Kiker G, Batchelor CG, Bridges T (2006a). From Comparative Risk Assessment to Multi-Criteria Decision Analysis and Adaptive Management: Recent Developments and Applications. *Environment International* 32: 1072-1093.

- Linkov I, Satterstrom FK, Seager TP, Kiker G, Bridges T, Belluck D, Meyer A (2006b). Multi-Criteria Decision Analysis: Comprehensive Decision Analysis Tool for Risk Management of Contaminated Sediments. *Risk Analysis* 26:61-78.

- Linkov I, Tkachuk A, Levchenko A, Seager T, Figueira J, Tervonen T (2007a). “A Multi-Criteria Decision Analysis Approach for Establishing Performance Metrics under Government Performance and Results Act: Example of Oil Spill Response.” In: Linkov, I., and Wenning, R., eds. *Risk Assessment and Decision Support for Ports and Critical Infrastructure*, Springer, 2007.

- Linkov I, Satterstrom FK, Steevens J, Ferguson E, Pleus RC (2007b). Multi-criteria decision analysis and environmental risk assessment for nanomaterials. *Journal of Nanoparticle Research* 9:543-554.